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A Novel Impulse Detector for Filtering of Highly Corrupted Images

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Abstract**—**As the performance of the filtering system depends upon the accuracy of the noise detection scheme, in this paper, we present a new scheme for impulse noise detection based on two levels of decision. In this scheme in the first stage we coarsely identify the corrupted pixels and in the second stage we finally decide whether the pixel under consideration is really corrupt or not. The efficacy of the proposed filter has been confirmed by extensive simulations.

Keywords**—**Impulse detection, noise removal, image filtering.

I. INTRODUCTION

IMPULSE noise removal in digital images is an important pre-processing step as images are often corrupted by impulse noise due to a noisy sensor or transmission errors. The goal of impulse noise removal is to suppress the noise while preserving the integrity of edge and detail information [1]. Most of the impulse noise filtering methods comprise order static filters utilizing the rank-order information of an appropriate set of noisy input pixels. These are usually based on the median filter and its derivatives. These filtering operations are typically applied uniformly across the image and also tend to modify pixels that are not affected by noise. Therefore, the effective removal of impulse noise is often at the expense of blurred and distorted image details [2].

In order to improve the performance of median filters, a variant known as switching median filter [3-4] has been proposed which combines the median filter with an impulse detector. In this approach, the impulse detector aims to determine whether the center pixel of a given filtering window is corrupted or not. If the center pixel is identified as an impulse, it is filtered otherwise left unchanged.

A number of techniques obtained by modifying the basic switching median filters have also been proposed. The progressive switching median filter [3] achieves the detection and removal of impulse noise in two separate stages. The weighted median filter and center-weighted median filter (CWMF) [5] are modified median filters which can handle the trade–off between the noise suppression and image detail preservation by giving more weight to the appropriate pixels of the filtering window. In multi-state median (MSM) filter [6], the out-put of the filter is adaptively switched among those of a set of CWM filters having different center weights.

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The tri-state median filter [7] is a modified switching median filter that is obtained by including a center weighted median filter into a basic switching median filter structure. Another filtering scheme given in [8] uses a difference-type noise detector and the noise detection-based adaptive medium filter. All these approaches require some kind of noise detection scheme as the switching action is performed on the basis of knowledge of corrupted pixels. Therefore, the impulse detection scheme should be able to accurately identify the presence of noisy pixels. The efficient impulse detection then translates into an improved performance of the filtering system.

We propose a switching median based filtering method where the presence of an impulse is computed in two stages on the basis of pixel values in a filtering window. In order to judge the performance of the proposed scheme, the results are compared with other filtering methods. The paper is organized as follows. The proposed method is illustrated in section II. Simulation results with different noise densities and images are presented in section III to demonstrate the improved performance of the filter. Finally, section IV presents the conclusion summarizing the overall findings of the study.

II. PROPOSED ALGORITHM

We assume that the image is of size M×N having 8-bit gray scale pixel resolution that is, $I \in [0, 255]$. In a 3×3 window $W_{m,n}^{(x)}$ at (m,n), the center pixel is defined as $x(m,n)$ and its neighbors as $\{x_k(m,n)\}_{k=1}^{8}$.

In the conventional switching median filter *y(m,n)* the filtered output for *x(m,n)* is given by,

$$y(m,n) \begin{cases} = median\left(W_{m,n}^{(x)}\right) \; ; & \left|median\left(W_{m,n}^{(x)}\right) - x(m,n)\right| > \text{threshold} \\ = x(m,n) & ; \text{otherwise} \end{cases} \quad (1)$$

The output of the impulse detector is represented by a binary flag image $\{f(m,n)\}$, where the $f(m,n) = 1$ indicates that the pixel *x(m,n)* is noisy ; for noiseless pixel $f(m,n) = 0$.

The general framework of this scheme is shown in Fig. 1. When the filtering process starts, two stage impulse detector decides whether the pixel under consideration is noisy or not. If the pixel under consideration is found noisy the switch S_1 selects the output of the median filter otherwise unfiltered input pixel is sent to the output.

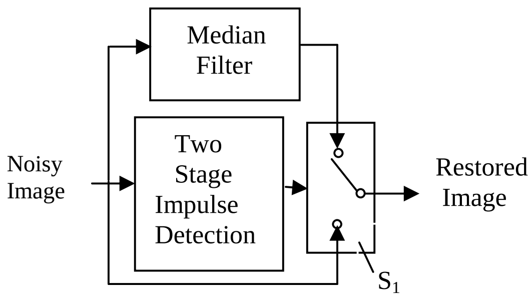

Fig. 1 Block Schematic for the Proposed Filter

In the proposed method, firstly, the noisy pixels are identified from the pixel values in window $W_{m,n}^{(x)}$ and then, if the pixel under consideration is found noisy, it is reconsidered in the bigger window, if the pixel under consideration is again found noisy, it is replaced by the median of the noise free pixels in the window. The algorithm works in the following manner:

Step 1:First stage impulse detector
Set $f(m,n) = 0$; for all (m,n) ;Read the input noisy image {x(m,n)}; Window size = (3×3)

For each window $W_{m,n}^{(x)}$ order the pixel values by rank.

$$R(m,n) = [r_1(m,n), r_2(m,n), ---, r_9(m,n)]$$

such that $r_1(m,n) \le r_2(m,n) \le --- \le r_9(m,n)$. (2)

If $(x(m,n) = r_1(m,n))$ or $(x(m,n) = r_9(m,n))$
$f(m,n) = 1$
end

Step 2: Second stage impulse detector
Consider output flag image of step-1 $f(m,n)$;
for all $(m,n)=1$;Read the input noisy image {x(m,n)};
Window size = (11×11)
For each window $W_{m,n}^{(x)}$ order the pixel values by rank.

$$R(m,n) = [r_1(m,n), r_2(m,n), ---, r_{121}(m,n)]$$

such that $r_1(m,n) \le r_2(m,n) \le --- \le r_{121}(m,n)$. (3)

Now compute the distance vector

$$D(m,n) = [d_1(m,n), d_2(m,n), ---, d_{120}(m,n)]$$

where $d_i(m,n) = |r_{i+1}(m,n) - r_i(m,n)|$ (4)

Step 3:
Find the first four largest distances $d_{\max 1}$, $d_{\max 2}$, $d_{\max 3}$ and $d_{\max 4}$ in $D(m,n)$ such that

$$d_{\max 1} = d_i(m,n) \text{ ; } d_{\max 2} = d_j(m,n);$$
$$d_{\max 3} = d_k(m,n) \text{ and } d_{\max 4} = d_l(m,n) \quad (5)$$

where $d_i(m,n) > d_j(m,n) > d_k(m,n) > d_l(m,n)$ (6)
m = min[i,j,k,l] ; n = max[i,j,k,l] ;

Step 4: Computation of maximum and minimum values of noise free pixels.

$$w_{\min} = r_{m+1}(m,n) \text{ and } w_{\max} = r_n(m,n) \quad (7)$$

end.

Step 5: Computation of noisy pixels

If $(x(m,n) < w_{min})$ or $(x(m,n) > w_{max})$
$f(m,n) = 1$
else $f(m,n) = 0$ (8)
end

Step 6: Noise filtering

$$y(m,n) = \begin{cases} med_{mn} & if \ f(m,n) = 1 \\ x(m,n) & if \ f(m,n) = 0 \end{cases} \quad (9)$$

Where med_{mn} denotes the median of the noise free pixels in the window under consideration. For filtering, firstly we consider window size=(3×3) and if the entire window is found noisy than window is made bigger ie (5×5)

At the end of the filtering the image {y(m,n)} represents the restored image.

III. Implementation and Simulation

In our experiments, three different images viz. 'Lenna' 'Peppers' and 'Baboon' are considered. The test images are corrupted with fixed valued salt-pepper impulses, where the corrupted pixels take on values of either 0 or 255 with equal probability. To evaluate the image restoration performance, mean square error (MSE) is used as the criterion. MSE is defined as,

$$MSE = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} (u(m,n) - y(m,n))^2 \quad (10)$$

where the image is assumed to be of size M×N. $u(m,n)$ and $y(m,n)$ are the pixel values of original and restored image, respectively at position (m, n).

The test images used in the study are corrupted by impulse noise with noise densities from 20% to 70% with steps of 10%. In order to judge the performance of the proposed method, the test images are also filtered by several popular, conventional and recently proposed filtering methods including standard median filter (Median I), median filter with threshold (Median II), center weighted median(CWM) filter, multi-state median (MSM) filter and progressive switching median (PSM) filter for comparison.

The proposed impulse noise detector is applied on the noisy images using 3×3 window in the first stage and using 11×11 window in the second stage. If the pixel under consideration is found noisy in both the windows, it is replaced by the median of the noise free pixels. In center weighted median filter, the window size used is 5×5. It has been observed that smaller window size does not yield good results. In case of PSM, the window size is switched between 3×3 and 5×5 according to the noise density in the image as suggested in [3] for its optimal performance. The MSE resulting from various experiments is shown in Table I to III for ‘Lenna’, ‘Peppers’ and ‘Baboon’ images, respectively.

TABLE I
MSE OF VARIOUS FILTERS FOR LENNA IMAGE

Filter	Noise Percentage					
	20	30	40	50	60	70
Median I	147	347	888	2003	3913	6483
Median II	106	321	863	1988	3867	6526
CWM	122	147	207	459.0	1187	3085
MSM	79	223	813	2604	6128	10421
PSM	96	227	372	702.0	1400	2587
Proposed Method	26.4	43.5	68.2	105	144	195

TABLE II
MSE OF VARIOUS FILTERS FOR PEPPERS IMAGE

Filter	Noise Percentage					
	20	30	40	50	60	70
Median I	126	353	913	2015	3929	6697
Median II	108	334	883	2073	3980	6703
CWM	81	110	185	420	1225	3144
MSM	92	260	821	2573	6390	10685
PSM	85	214.6	388	765	1473	26966
Proposed Method	15.6	28.8	46.4	77	114	156

From these tables it can be easily observed that the proposed method outperforms the other filtering schemes at high noise levels. At low noise level also, the performance of the proposed scheme is better than most of the methods used for comparison. MSM is the only filtering system whose performance is better than the present system in case of ‘Baboon’ image with low noise level (up to 10%). However, for the other two images i.e. ‘Lenna’ and ‘Peppers’, the proposed scheme outperforms all other filters shown in Tables I and III including MSM filter for the noise level more than 10%. Fig. 2 (a-h) shows the output images of various filtering methods considered in the study for 50% noise density. It can be seen that the proposed impulse detector based filtering method successfully preserves the details in the image while at the same time efficiently removing the noise.

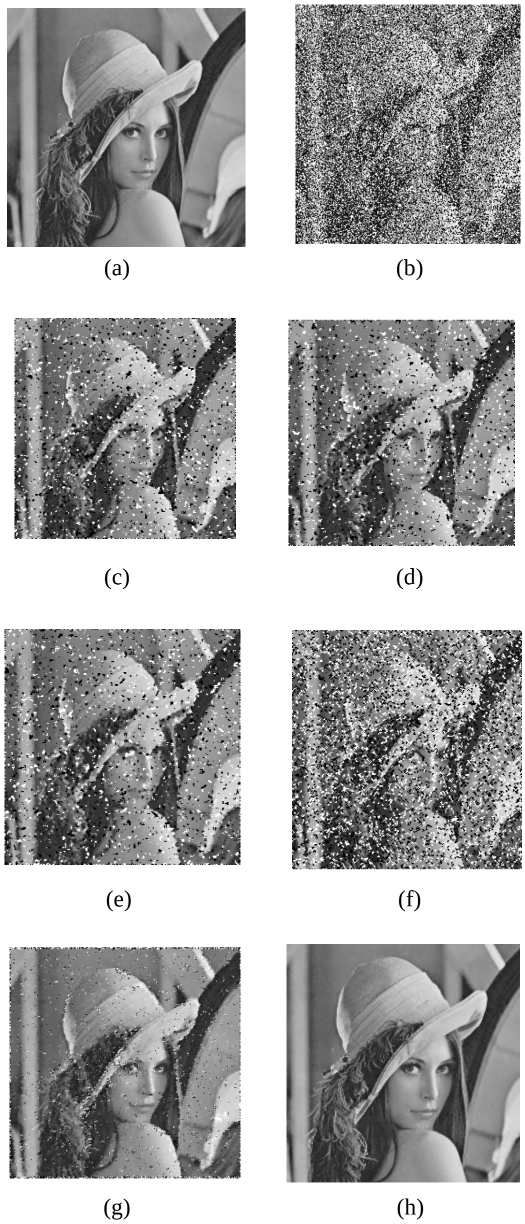

Fig. 2 (a) Original image (b) Noisy image (c) Output of Median (d) Output of median with Threshold (e) Output of CWM (f) Output of MSM (g) Output of PSM (h) Proposed

TABLE III
MSE OF VARIOUS FILTERS FOR BABOON IMAGE

Filter	Noise Percentage					
	20	30	40	50	60	70
Median I	733	966	1535	2647	4412	6965.7
Median II	578	851	1447	2559	4358	6914.2
CWM	596	637	726.6	986	1775	3572.6
MSM	310	499	1075	2844	6159	10206
PSM	538	715.7	994	1466	2212	3327.1
Proposed Method	159	242	323	410	496	595

IV. Conclusion

A filtering scheme based on the local contents of the window under consideration is presented for restoration of noisy images. The fundamental advantage of the proposed method over other methods is that the detection of corrupted pixels is very efficiently performed by the new impulse detection scheme. This efficient detection is translated into improved performance of the filtering system, as the pixel value is modified only when the noise is present in the pixel resulting in better detail preservation in images. The proposed scheme is specifically well suited for high noise levels where it out performs all other methods considered in the study.

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